

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.



(NASA-CF-146424) PROJECT PLAN HYDROGEN
ENERGY SYSTEMS TECHNOLOGY. PHASE 1:
HYDROGEN ENERGY SYSTEMS TECHNOLOGY STUDY
(Jet Propulsion Lab.) 25 p HC \$3.50

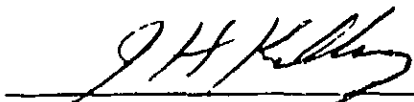
N76-18678


CSCL 10B G3/44 19072
Unclas

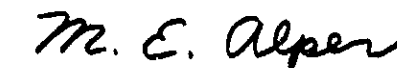


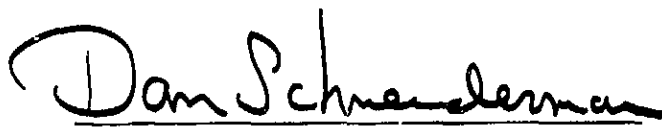
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA


PROJECT PLAN
HYDROGEN ENERGY SYSTEMS
TECHNOLOGY
PHASE I
HYDROGEN ENERGY SYSTEMS
TECHNOLOGY STUDY
1200-194 October 30, 1974


J. H. Kelley
Study Manager
Jet Propulsion Laboratory


D. R. Stone
Program Manager
NASA Office of Energy Programs


M. E. Alper
Manager of Energy and Environmental Systems
Jet Propulsion Laboratory


D. Schneiderman
Civil Systems Program Office Manager
Jet Propulsion Laboratory


R. D. Ginter
Director of Energy Systems
NASA Office of Energy Programs

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

CONTENTS

SECTION

I.	INTRODUCTION	1
II.	APPROACH	4
III.	WORK PLAN	6
	A. SCOPE OF WORK	6
	B. METHODOLOGY	14
	C. STUDY EMPHASIS	15
IV.	MANAGEMENT PLAN	16
	A. ORGANIZATION	16
	B. REVIEW	16
	C. REPORTS	18
V.	SCHEDULE	19
VI.	INTERFACES	21
VII.	RESOURCES	22

FIGURES

1.	Hydrogen Energy Systems Technology Study Overview	4
2.	Task Flow Diagram	7
3.	HEST Study Organization	16
4.	Working Schedule of HEST Study	20

1. INTRODUCTION

During the past few years there has been increased recognition of the potential of hydrogen as a means for converting, storing, and transporting energy. Hydrogen, as a synthetic fuel, has a unique position in that it is clean-burning and can be produced from a renewable and readily available raw material, water. Hydrogen could serve as a clean fuel for industry, homes and transportation; as a medium for energy storage and transmission, and as a fundamental raw material for industrial and chemical processes. Hydrogen is currently used in many industrial processes, particularly in the manufacture of ammonia for such end products as fertilizers, and in petroleum refining; its use may be expanded in the future as replacements for natural gas and oil and other transportable fuels are sought by many segments of the economy.

The expanded use of hydrogen in the future is largely dependent upon its availability in large quantities at a commercially competitive price. For example, there is now an immediate need for a vastly increased production of hydrogen for the manufacture of fertilizer to help overcome the present and future worldwide shortage of food. The problem is that, at present, hydrogen is made primarily from natural gas -- itself in critical short supply. Hydrogen can theoretically be made from any hydrocarbon, in particular, by coal gasification. It can also be made by the decomposition of water using solar or nuclear energy or other energy sources. For these and many related reasons, comprehensive projections of energy needs show increasing use of hydrogen in various processes and applications. Hydrogen has been proposed, in some scenarios, as the universal synthetic fuel and energy medium of the future. While this extreme position may not be justifiable, hydrogen technology and systems may become an important ingredient of the solution to the U.S. energy problems.

Within the framework of future aerospace energy needs, hydrogen also will play an important role. Sources of hydrogen must be assured for the Space Shuttle program and other space systems, hydrogen will be needed to support the manufacture of synthetic aviation fuels. At some time in the future, hydrogen-fueled aircraft may come into service. In order to define

its own program needs in these areas, NASA needs to develop a thorough understanding of the technological and economic factors associated with the production and use of hydrogen. NASA has continued studies and research on hydrogen as applied to these uses and through nearly 20 years of experience has developed an extensive background in hydrogen technology as applied to problems in materials, storage, production, and end-use.

NASA is extending these studies and research on hydrogen in coordination with other appropriate Federal agencies and industry to consider the total National needs for hydrogen technology. The Hydrogen Energy Systems Technology (HEST) Study which will be conducted during FY-75 is the first phase of a planned two-year program definition effort. This first phase will develop an overview of the potential need for hydrogen in the Nation's economy as a function of time in order to identify and define the technology requirements for the most promising approaches to meet that need.

This study will result in an assessment report submitted to the NASA Office of Energy Programs for use in evaluating the state of development and the potential of hydrogen energy systems technology. This assessment may provide the basis for FY 77 National energy R&D program decisions regarding hydrogen. Primary emphasis will be placed on more cost effective and energy effective means of production, with a lesser effort devoted to the use of hydrogen for energy storage and transmission, and to end-use applications.

A second phase in FY-76 will identify, define, and develop in considerable detail a National Hydrogen Energy Systems Technology Program Plan in time to permit a rational start in FY-77.

The objectives of the initial study effort are:

- To determine future demand for hydrogen based on current trends and anticipated new uses.

- To identify the critical research and technology advancements required to meet this need considering, to the extent possible, raw material limitations, economics, and environmental effects.
- To define and recommend the scope and pace of a National Hydrogen Energy Systems Technology Program and outline a Program Development Plan.

II. APPROACH

The Hydrogen Energy Systems Technology Study will be implemented by a Jet Propulsion Laboratory (JPL) team which will be responsible for the completion of each task (identified in Section III). The JPL study manager will work closely with NASA Headquarters and will chair an inter-Center NASA Working Panel, which will provide broad technology support and focus the activities and participation of NASA Centers. The study will be supported by ad hoc working groups and by a JPL-formed Review Group to assure that the study goals are effectively and credibly accomplished. This mechanism is sketched in Fig. 1.

The inter-Center NASA Working Panel will provide close coordination with ongoing related NASA studies to avoid duplication and maximize mutual cooperation with these activities. Members assigned to the Working Panel by the Centers will assure appropriate Center representation on the specific ad hoc groups. Ad hoc working groups, drawing personnel and expertise from the NASA Centers, government, and non-government sectors, will be formed when necessary to support specific tasks of the study. Also, recognized experts from other government agencies, industry supported institutions, and universities will be asked to participate in a Review Group to critique the study approach and progress and to supply information in technical and nontechnical areas. As appropriate, they may also be asked to participate in working groups.

In identifying hydrogen demand scenarios (Task 1), it is recognized that the conclusions will be a function of the assumptions and that alternative assumptions should be considered to yield a "spread" in results. This spread may or may not affect the technology conclusions, but it is likely to affect the schedule of when items of technology will be required.

Certain subtasks not critical to the formal study objectives will consist of summaries of conclusions generally agreed to by experts in the field and on

the basis of cited literature sources. Statements regarding identified technical requirements and whether further work is recommended will be made. Portions of Tasks 1, 2, and 4 will be treated in this manner.

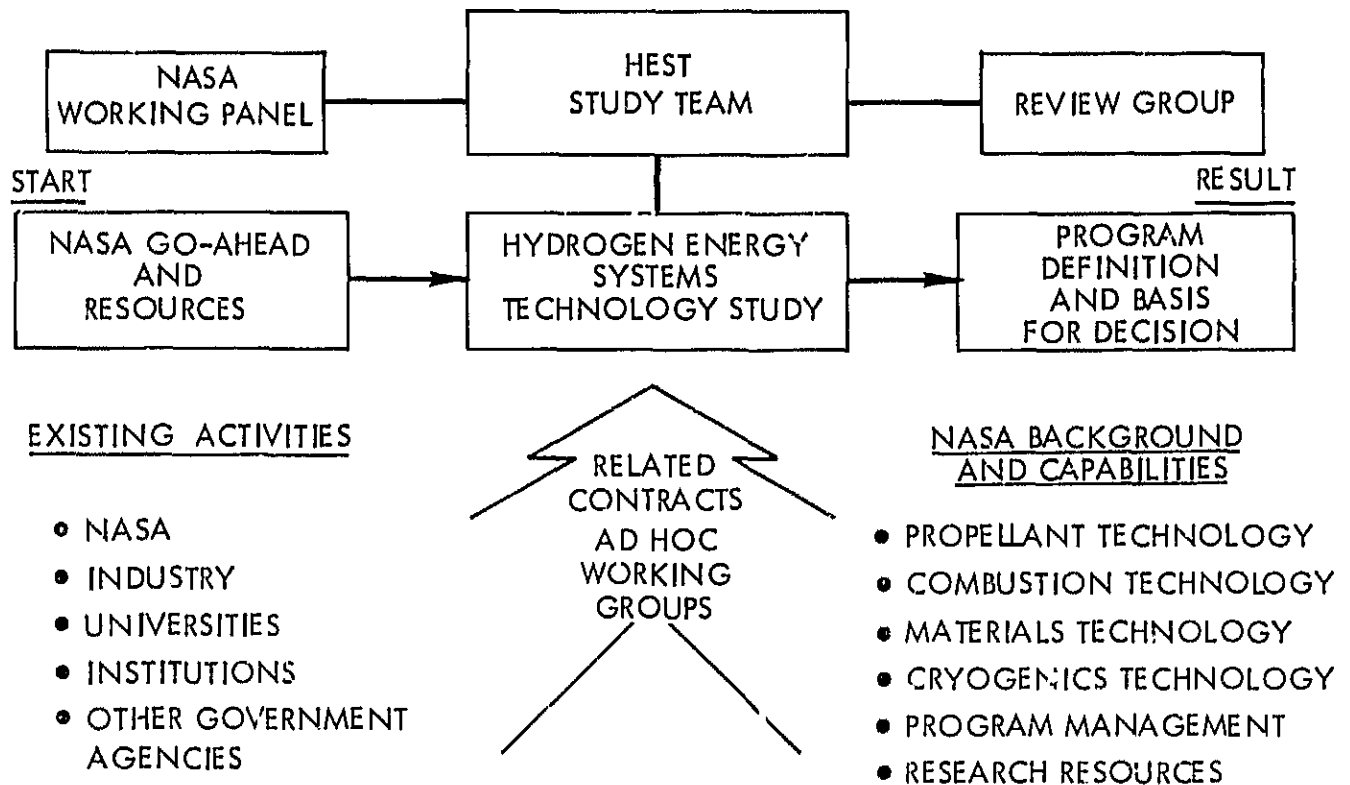


Fig. 1. Hydrogen energy systems technology study overview

III. WORK PLAN

A. SCOPE OF WORK

The work to be performed in order to meet the objectives of this study is divided into six distinct tasks, some having several subtasks. Statements describing each of these tasks together with outlines of its content follow. Figure 2 depicts the functional relationship of each task to the others.

TASK 1. HYDROGEN DEMAND

a) Utilization

Statement: Identify and characterize current and potential new uses of hydrogen.

Outline: Consider current major uses of hydrogen, such as:

Ammonia manufacture for fertilizers, explosives, etc.

Petroleum refining

Desulfurization of fuels

Methanol production

Plastics

Aerospace fuel

Consider new and potential uses of hydrogen such as:

Coal and oil shale conversion to hydrogen-based liquid fuels.

Convert low-BTU gas to mixed or high-BTU gas.

Electric utility use (dispersed power generation via fuel cells, peaking, remote siting).

Direct reduction of ores.

Industrial fuel.

Residential and commercial fuel.

Transportation system fuel (ground, sea, air).

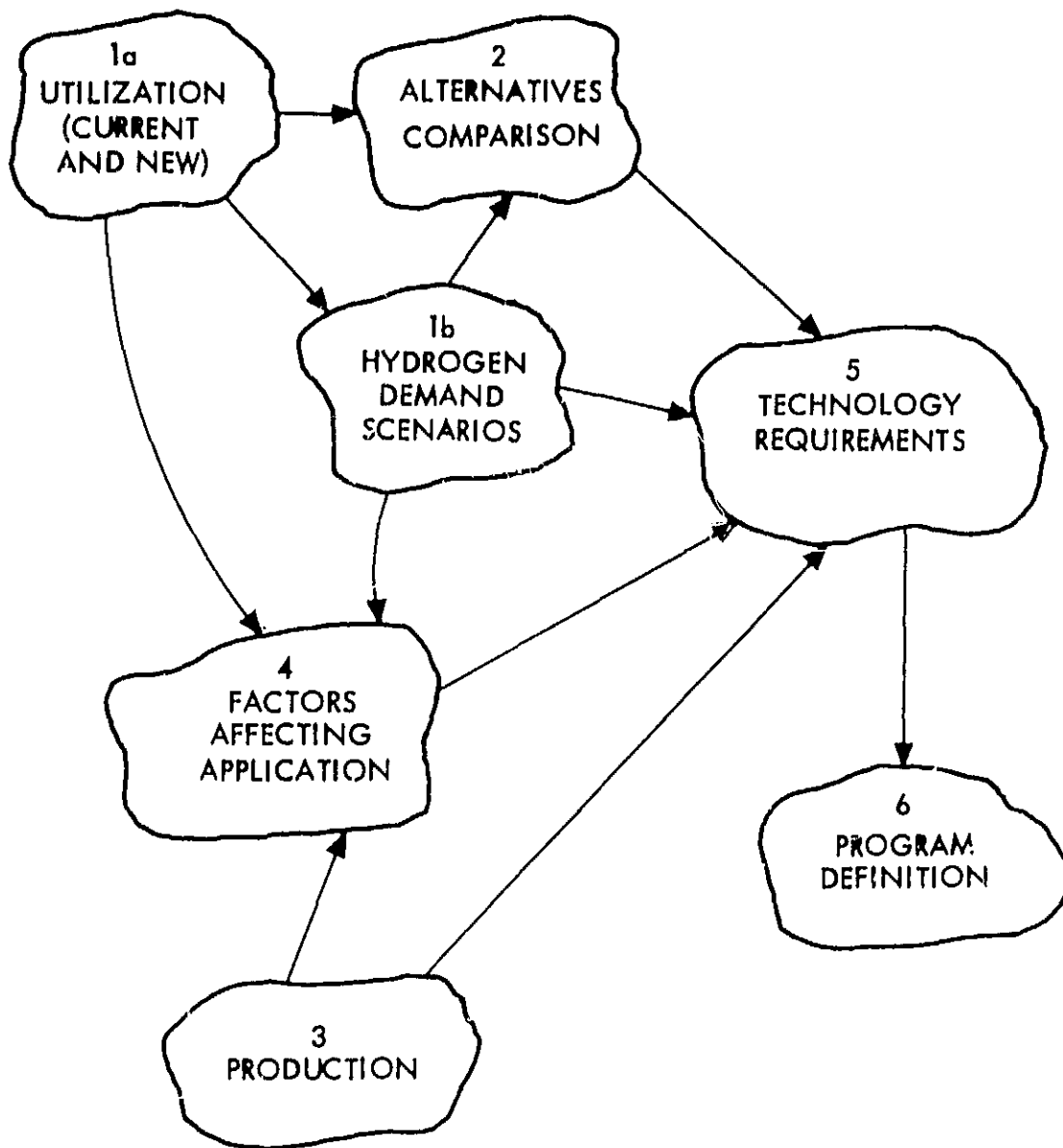


Fig. 2. Task Flow Diagram

L) Hydrogen demand scenarios

Statement: Select an appropriate energy-demand model and use it to formulate hydrogen-demand scenarios in order to predict hydrogen demands as a function of time.

Outline: Review existing energy demand/supply models (NPC, Ford Foundation, DOL, and IGT for EPA), and select one model as the most appropriate for this study.

Based on this model, project the future hydrogen demand as a function of time. The spread in total hydrogen demand will be shown considering:

1. Current trends in hydrogen use.
2. Anticipated new uses of hydrogen from Task 1a.
3. Best and worst domestic fuel (fossil) supply situations.

TASK 2: ALTERNATIVES COMPARISON

Statement: Consider the potential advantages and disadvantages of hydrogen carriers and alternatives such as methanol and syngas, and compare their potential to that of hydrogen for selected applications in order to assess the impact on future hydrogen demand as generated in Task 1b.

Outline: Compare hydrogen to alternatives per the task statement (above) for the following:

Electric utility energy transmission: hydrogen vs known methods.

Electric utility energy storage and load leveling with hydrogen, methanol, syngas (compare with pumped storage and other well-known techniques).

Residential applications: hydrogen vs methanol, syngas, coal, and electricity.

Ground, air, and sea transportation applications: hydrogen vs methanol, considering storage, engine modifications, etc.

Other applications identified during the study.

Comparative study, combining hydrogen use scenarios for selected applications with alternatives to determine impact on hydrogen demand and possible implementation, considering economics, feedstock, safety, and environmental impacts.

TASK 3: HYDROGEN PRODUCTION

Statement: Survey and define all known hydrogen production processes that have large-scale production potential. Define current state-of-the-art and technology deficiencies.

Outline: Identify key issues, state-of-the-art, pro and con arguments, recent and ongoing work, pertinent references, required interfaces, technology deficiencies, and byproduct recovery potentials for the following hydrogen production schemes:

Steam reforming of natural gas, naphtha, and other petroleum products

Electrolysis

Coal-based thermochemical

Closed cycle thermochemical

Direct thermal dissociation

Direct photolysis

Electro-chemical photolysis

Photosynthesis

Bioconversion

Others

TASK 4: FACTORS AFFECTING APPLICATION

a) Storage, Transmission, and Distribution

Statement: Investigate the technology requirements for the storage, transmission, and distribution of hydrogen.

Outline: Identify methods for storage, transmission, and distribution.
Evaluate technical performance for current and projected state of the art storage, transmission, and distribution.
Summarize deficiencies in current technology for gaseous and liquid hydrogen handling, storage, and distribution.
Establish comparative economics of each method.

b) Materials

Statement: Investigate the problems of construction materials compatibility in large-scale hydrogen production, handling, and consumption.

Outline: Review the technology of hydrogen/materials compatibility as developed by other studies and specialists in the field (e.g., embrittlement).
Summarize the trends and deficiencies anticipated in the areas of materials application and compatibility.

c) Safety

Statement: Identify and assess the safety problems that may be associated with the increased production and use of hydrogen.

Outline: Review current safety practices and procedures.
Identify the nature of hazards of projected large-scale hydrogen use.
Identify the safety-related differences between hydrogen, the energy and chemical sources it could replace, and its potential competitors.

d) Industry Acceptance and Adaptation

Statement: Investigate the possible inhibitors that would affect the industrial acceptance of and adaptation to the use of hydrogen as an energy source and direct or supplemental chemical feedstock.

Outline: Review patterns of institutional barriers and other forms of inhibitors as developed by other studies and specialists in the field.
Identify current and past hydrogen usage inhibitors.
Identify the usual inhibitions of the energy and processing industry.
Postulate the likely inhibitors that would affect hydrogen acceptance.

e) Environmental and Societal Effects

Statement: Summarize the environmental and societal problems and societal problems and effects that would be created by the increased production, transmission, and use of hydrogen.

Outline: Review the environmental and societal findings of other studies and specialists in the field.
Identify the main environmental and societal-impact issues associated with the increased production and use of hydrogen.

TASK 5: TECHNOLOGY REQUIREMENTS

Statement: Assess the state-of-the-art in hydrogen technology.
Summarize and assess the research and technology advancements required to meet the anticipated demands.

Consider the technology requirements for increased production, storage, transmission, distribution, and end-use at levels defined in the hydrogen demand scenarios.

Outline: Review the findings of other studies and obtain the reviews of specialists concerning technological requirements.
Review current and planned Research and Technology of both government and industrial institutions.
Based on the results of the previous tasks, identify the critical technology advancements required to meet identified needs.

TASK 6: PROGRAM DEFINITION

Statement: Provide the program definition required for FY-77 National Energy Program decisions regarding hydrogen.

Outline: Determine the relationship of ongoing technology programs within the Government and industry.
Identify research needed to evaluate critical technology requirements.
Identify systems and economic benefit analyses required to evaluate potential technology options.
Identify funding needs in order to satisfy the technology requirements identified in Task 5.
To the extent possible, assess impacts of various funding levels.
Draft a Program Development Plan for FY-76.

B. METHODOLOGY

The study tasks described in the previous outlines will be completed by gathering and evaluating appropriate data from recently completed and ongoing studies and by sampling the most current views of recognized experts. The data for Tasks 1a, 2, 3, and 4 will be assessed against the following criteria as applicable.

Concept: What is or seems to be workable?

Time: What technologies have a chance of development during the time frames of 1975 to 1985, 1985 to 2000, and beyond 2000?

Availability: What are the relative demands on natural resources (efficiencies, raw materials, manpower, etc.)?

Practicality: Which approaches pose critical operational problems?

Environmental Impacts: Which approaches pose potential environmental problems?

Contribution Scale: Does this technology potentially solve the problem or only a portion of it, and what portion? What is its potential contribution in relation to the R&D effort?

Tasks 1 through 4 provide the frame of reference for the technology requirements determined in Task 5. The work on Tasks 1 through 4 will be interactive where schedules permit, but no attempts will be made to iterate conclusions after task completion. Task 5 will make interpretive adjustments if necessary. Task 6 will be derived from the results of Task 5.

C. STUDY EMPHASIS

Non-uniform levels-of-effort are assigned to the several tasks. Because cost and resource-effective hydrogen production will probably provide the greatest resistance to the development of a hydrogen based economy, Hydrogen Production Methods and Technology Requirements are expected to require the greatest amount of study. Listed below are the percentages of total study effort that are expected to be devoted to each of the tasks.

Task 1 Hydrogen Demand	10%
Task 2 Alternatives Comparison	10%
Task 3 Hydrogen Production	25%
Task 4 Factors Affecting Applications	5%
Task 5 Technology Requirements	40%
Task 6 Program Definition	<u>10%</u>
	100%

IV. MANAGEMENT PLAN

A. ORGANIZATION AND ASSIGNMENTS

The Study will be conducted during FY-75 by JPL personnel with support from NASA Center personnel, consultants, and the results of relevant contracts. Management of the effort is assigned to the Jet Propulsion Laboratory by the Office of Energy Programs. Mr. James H. Kelley of JPL will serve as the study manager. To implement the study he will form a JPL study team and an Inter-Center Working Panel with a member from each participating Center. Members designated to the Working Panel by the Centers are:

James H. Kelley, Chairman	JPL
A. Douglass Alexander	ARC
Earl J. Montoya	FRC
Eugene A. Laumann	JPL
W. Richard Downs	JSC
Lester J. Owens	KSC
Robert Witcofski	LaRC
Donald Bogart	LeRC
William D. Powers	MSFC

Ad hoc working groups will be formed when necessary to support specific tasks of the study. Figure 3 depicts the study organization and relationships to ongoing and emerging contracts. The JPL study group will be responsible for completion of all tasks of the work plan based on Working Panel inputs and recommendations.

B. REVIEW

Review functions will be performed by knowledgeable personnel from other government agencies, industry-related institutions, and universities. The objectives of these functions will be to review the study results and advise the study management such that the study will be kept relevant, realistic, and timely. In addition, some of these individuals will participate in working groups as appropriate.

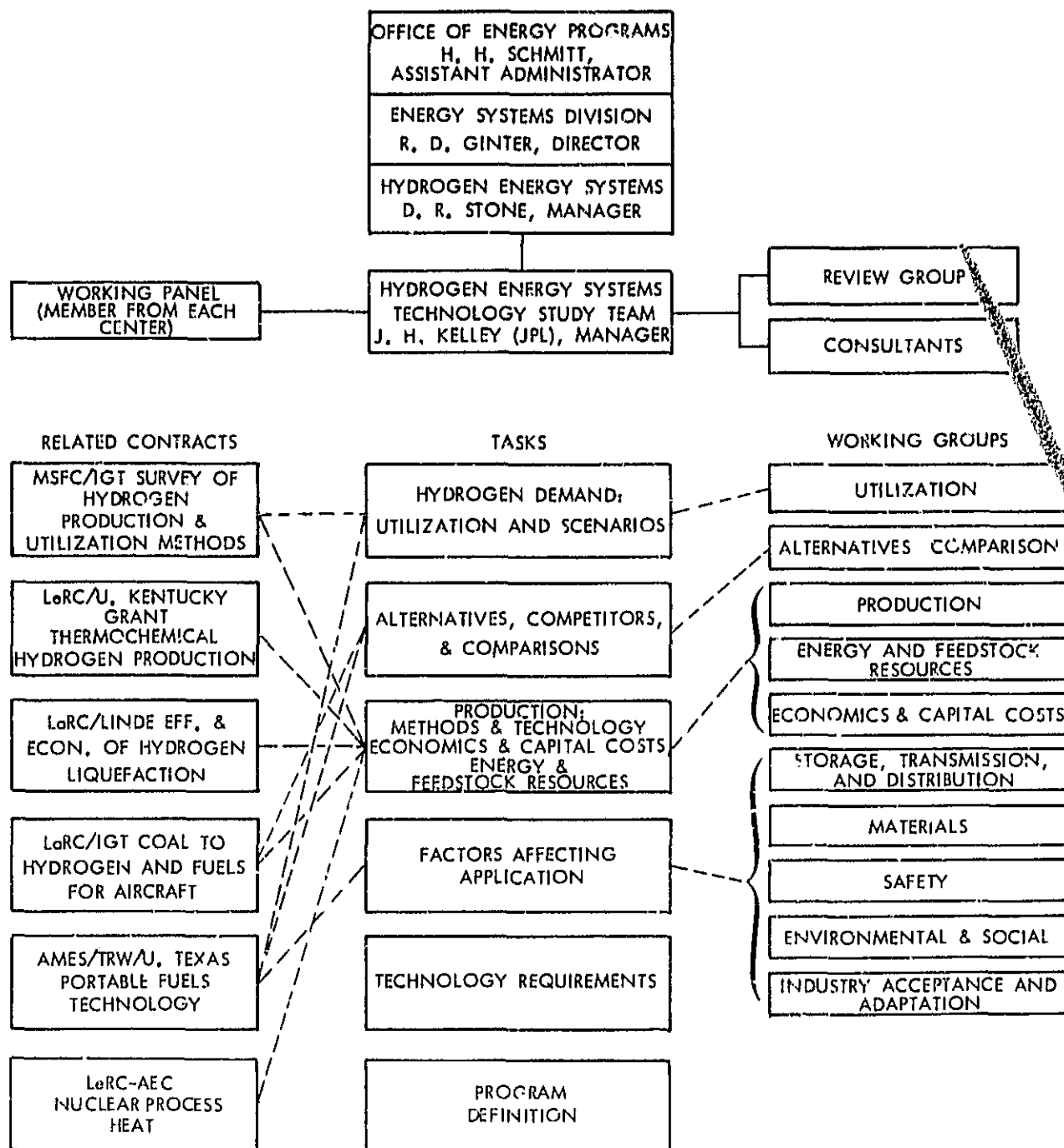


Fig. 3. HEST study organization

The Reviewers will provide information to the study manager, the working panel and the working groups as to other efforts the study should relate to, potential impacts which may have been overlooked, data which would be of value and courses of action which would improve the total effort.

JPL will formulate a list of nominees for the review function and invite them to participate. Two reviews of the study will be held, one in February and one in May. Additional meetings with working groups will be scheduled as needed.

Two-day Formal Reviews will be conducted if feasible. At least one week prior to these Formal Reviews, an agenda and copies of draft reports will be delivered to each reviewer. This will supplement the Working Panel minutes and other appropriate informative correspondence they will have received during the study. The review meetings will be structured so that the study status and results are presented by the study manager, and the reviewers are given an opportunity to ask questions of the manager, the Working Panel members and key JPL study team participants. The reviewers will be asked to critique the study at that time and to submit further, written critiques if they care to. Minutes of the meetings will be published and action items will be called out. Followup of the action items will be documented.

C. REPORTS

An informal interim report will be prepared prior to the February Review and a final study report will be submitted in June, followed by an oral report at NASA Headquarters. The final study report will be drafted prior to the May Review. The final report will be modified to make corrections and incorporate views of the Review Group, as appropriate. Dissenting or minority opinions of Reviewers will be published as an appendix of the report. The report is the tangible product of the HEST Study. It will be addressed to the Office of Energy Programs, and will be distributed to all study participants including Review Group members, to each NASA Center, and to other institutions and individuals as appropriate.

V. SCHEDULE

The overall schedule of the HEST Study is shown in the milestone chart of Fig. 4.

Individual task schedules will be written by the cognizant Working Groups early in October and reviewed by the Panel at its October meeting. A specific listing of meetings and Reviews is as follows:

September 4 & 5	Working Panel meeting	JPL
October 17 & 18	Working Panel meeting	LeRC
December 9-11	Working Panel meeting	LaRC
January 8 & 9	Industry Presentations	JPL
February 4-6	Formal Review and Panel Meeting	JPL
March 11 & 12	Working Panel meeting	JPL
April 24 & 25	Working Panel meeting	MSFC
May 21-23	Formal Review and Working Panel meeting	JPL
June 26	Presentation of results	HQ

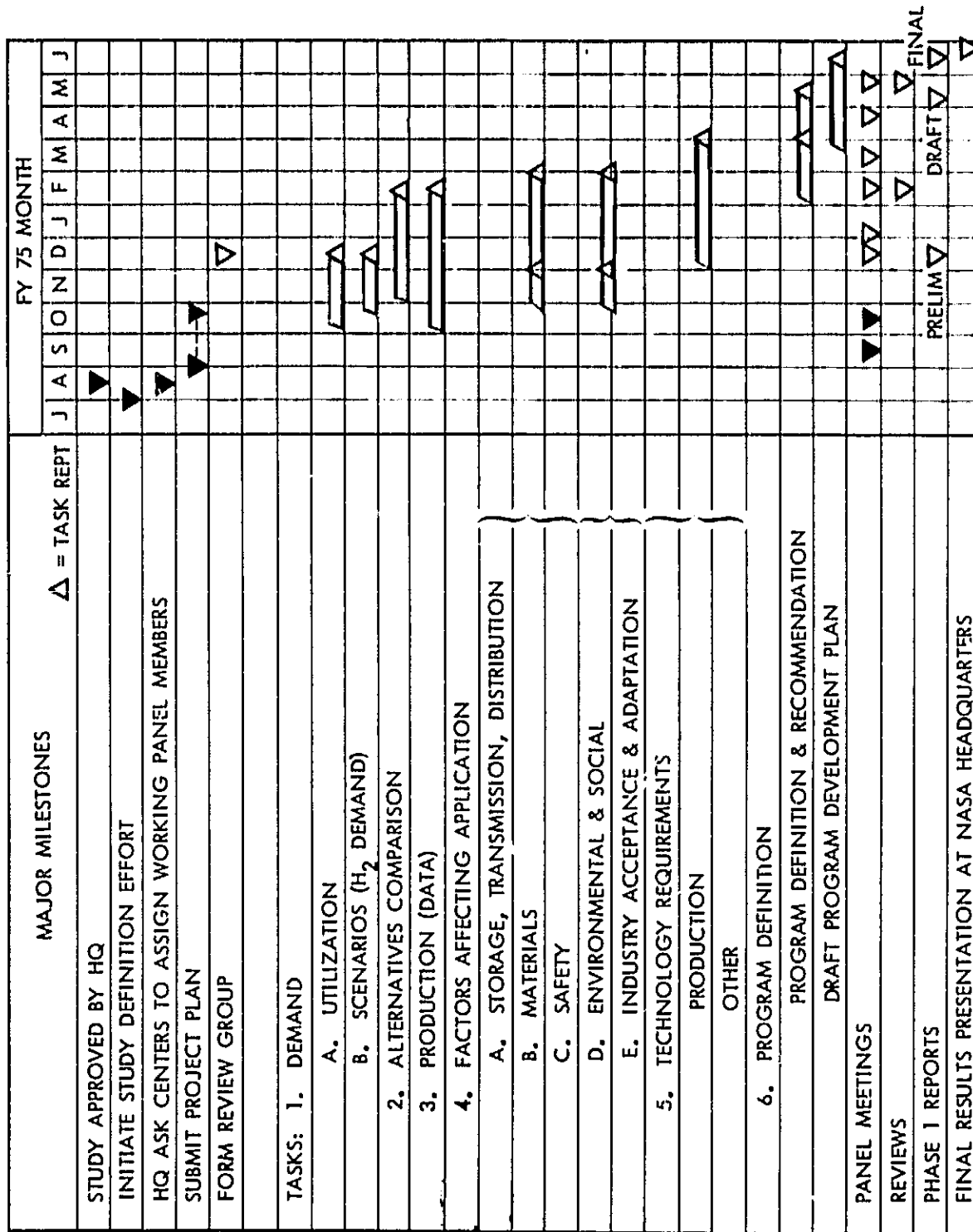


Fig. 4. Working schedule for HEST study

VI. INTERFACES

Interfaces with NASA Headquarters and the interfaces internal to the study are described in the Management Plan. Major related contracts and studies which this study will draw information from and establish synergistic relationships with are:

- MSFC Contract with IGT on Production and Utilization of hydrogen.
- Ames Contract with TRW & Univ. of Texas on Portable Energy Technology Assessments.
- Ford Motor Company sponsored effort at JPL: "Automobile Power System Evaluation Study".
- Langley Contracts with Linde and IGT on near term hydrogen production and liquefaction processes and efficiencies.
- Lewis work with AEC on the use of nuclear process heat for the production of hydrogen from coal.
- EPRI Contract with IGT: "Off-Peak Power to Produce Industrial Hydrogen".

Completed and documented studies which will serve as points of departure for this study include

- The JSC Summer (73) study, "A Hydrogen Energy Carrier" under NASA Grant NGT 44-005-114, published in two volumes in Sept. 1973, and
- The IGT study sponsored by AGA and published in Aug. 1972: "A Hydrogen Energy System".
- The LaRC summer study: The Energy Dilemma and its Impact on Air Transportation.

VII. RESOURCES

The following Resources directly support this study:

RTOP 778-60-01, \$300 K (FY75)

RTOP 647-20-03, \$56 K (FY74 carryover)

NASA Center manpower support at levels to be determined.